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LIMITS OF THE PRACTICAL APPLICATION OF THE LINEAR THEORY OF LIF--ETC(U)
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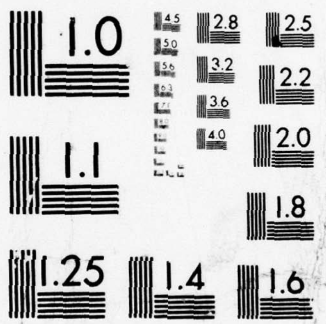

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FOREIGN TECHNOLOGY DIVISION

LIMITS OF THE PRACTICAL APPLICATION OF THE LINEAR THEORY OF LIFTING SURFACES TO THE CALCULATION OF WING AERODYNAMIC CHARACTERISTICS

by

S. D. Yermolenko and A. V. Rovnykh

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А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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LIMITS OF THE PRACTICAL APPLICATION OF THE LINEAR THEORY OF LIFTING SURFACES TO THE CALCULATION OF WING AERODYNAMIC CHARACTERISTICS

S. D. Yermolenko and A. V. Rovnykh

As we know, the well-developed linear theory of lifting surfaces is based on the assumption that the angle of attack is small, and the vortex film is infinitely thin and lies in the plane of the wing chord. And although the limits of the applicability of the linear theory would seem to be clear from the simplifying assumptions upon which it is based, this question must be considered in more detail, since up to now, unfortunately, there are still rather varied opinions on the unconditional reliability of results obtained for wings with linear dependences of the lift and axial moment coefficients on the angle of attack. This opinion is based on the fact that in spite of the assumption of the smallness of angles α,

the total aerodynamic forces, and often even the axial moment determined by methods of the linear theory completely satisfactorily agree with the experimental data in virtually the entire range of subcritical values of the angles of attack of wings with both simple and complex planforms [1, 2].

However, as experience shows, when there is a linear dependence of coefficients c_y and m_z on the angle of attack for the wing as a whole, the analogous dependences for its cross section are not necessarily linear.

As an example, Figures 1 and 2 give the results of wind tunnel tests of models of swept and so-called composite wings with rather large aspect ratios (λ = 5 and 3, 2). They also show calculations of the aerodynamic characteristics of these wings according to the linear theory of the lifting surface. It is evident from the analysis of the aerodynamic characteristics that the dependences of the lift and axial moment coefficients on the angle of attack are virtually linear in both wings, whereas the corresponding coefficients of the cross sections, at least over part of the wing span, are essentially nonlinear. The nonlinear effects are most clearly manifested in the characteristics of the end cross sections in the swept wing, and also near the joint of the wing center section with the cantilevers in the composite wing.

Fig. 1. KEY: (1) cross section. (2) Experiment. (3) Linear theory [1]. (4) Nonlinear theory [3].

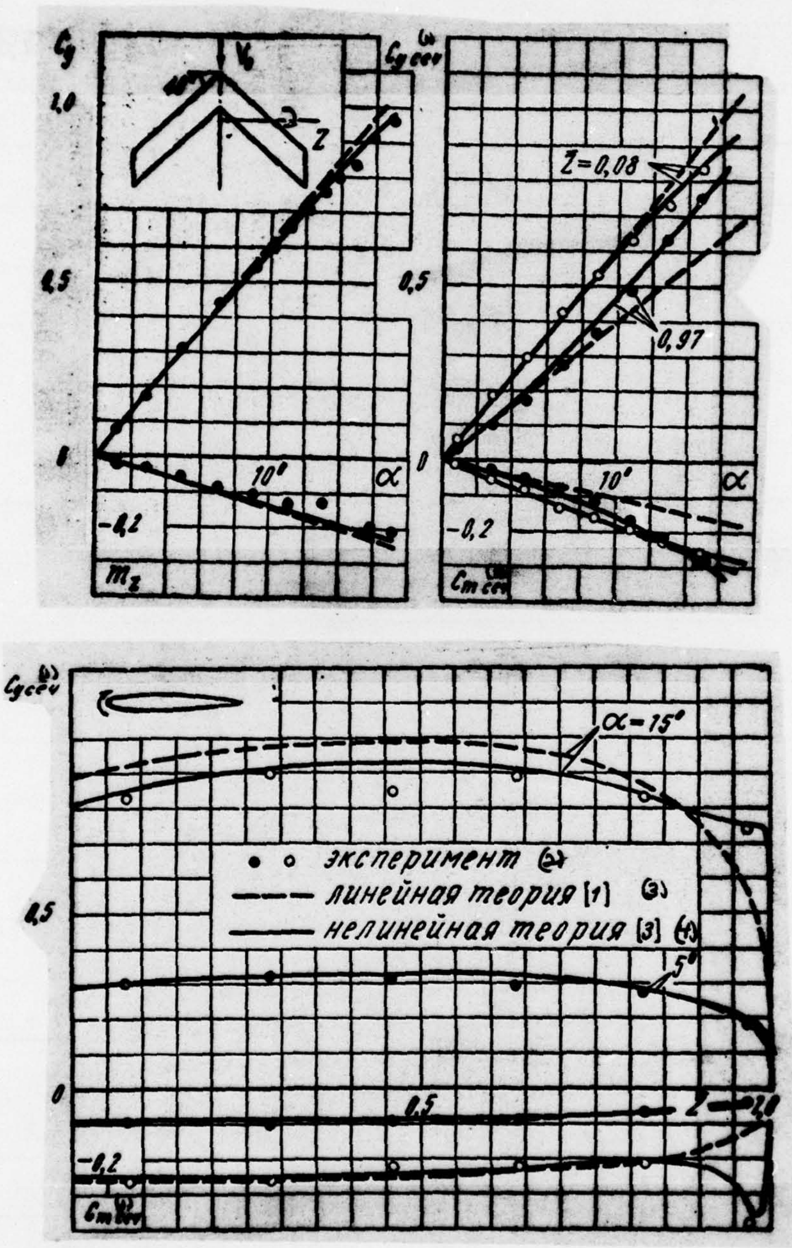
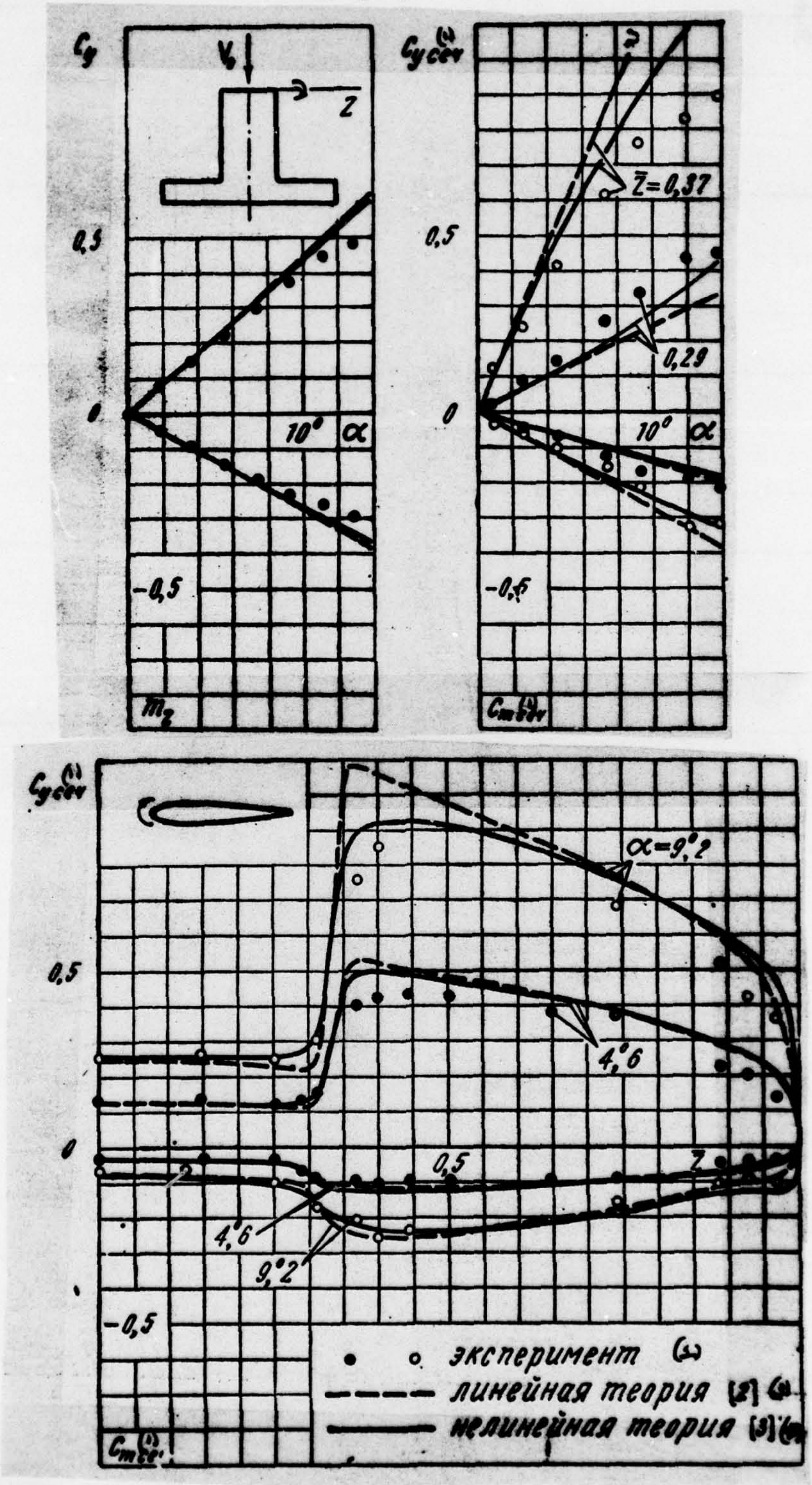


Fig. 2. KEY: (1) cross section. (2) Experiment. (3) Linear theory [2]. (4) Nonlinear theory [3].



Thus, even for wings with rather large aspect ratios and small angles of attack (α = 10-15°), the linear theory can result in considerable errors during the calculation of the local aerodynamic loads.

The lower the aspect ratio of the wing, the lower the effectiveness of the linear theory of lifting surfaces. The linear dependence of the lift and axial moment coefficients on the angle of attack and large inductance compared to wings with normal aspect ratios are characteristic of wings with small, in particular, very small aspect ratios. The center of pressure of the aerodynamic forces of these wings moves intensively toward the trailing edge with the increase in the angle of attack. The linear theory does not reveal these peculiarities, and it gives the incorrect results

when calculating the characteristics not only of the cross section, but also of the wing as a whole, in a large portion of the range of angles of attack of practical interest (Fig. 3). This occurs because the vortex system at its base does not correspond to actual flow about a wing at large angles of attack. In this case, the vortex wake behind the wing and on its upper surface is very thick, varying over the chord and the span.

Fig. 3. KEY: (1) Experiment (plate). (2) Linear theory [1]. (3) Nonlinear theory [3].

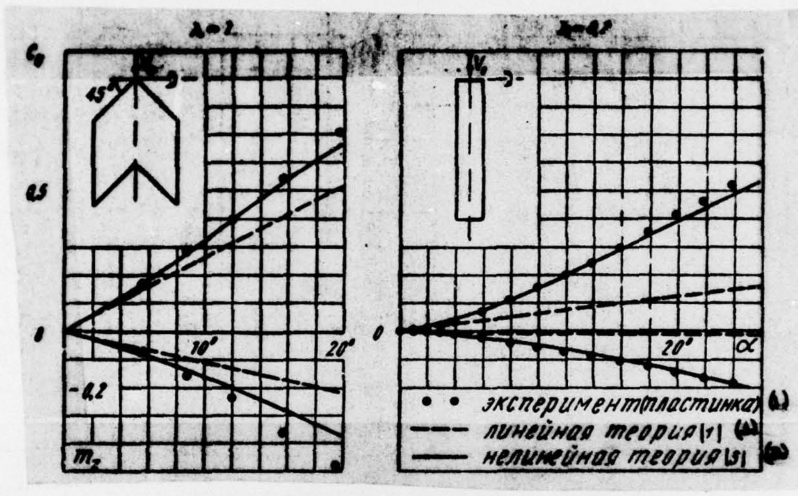
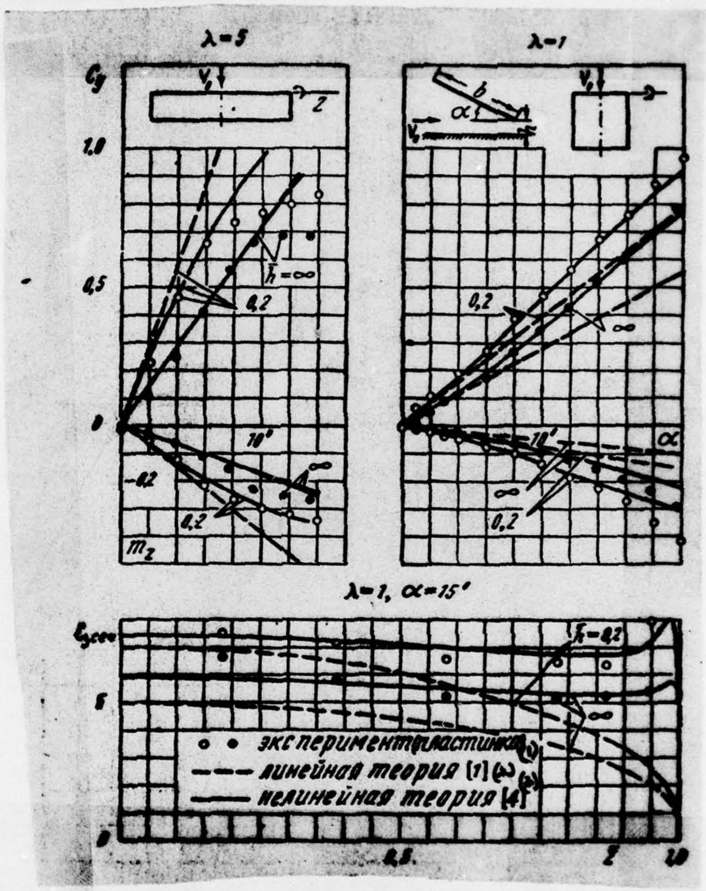


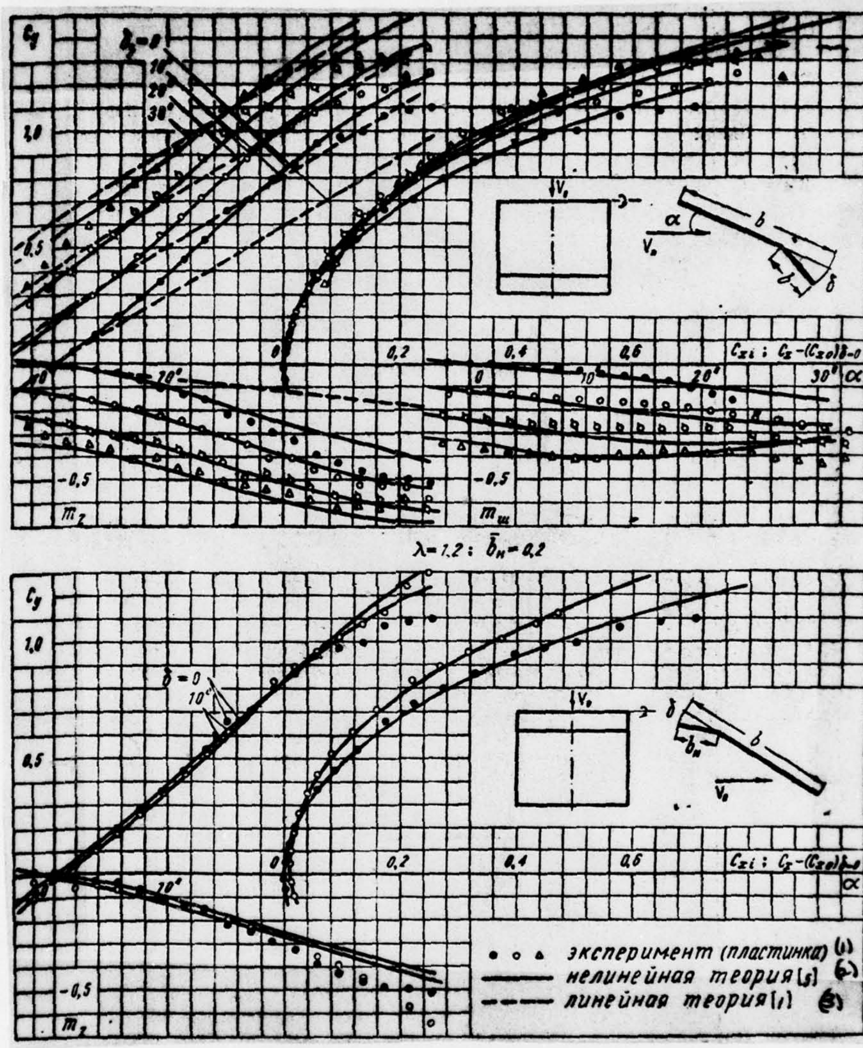
Fig. 4. KEY: (1) Experiment (plate). (2) Linear theory [1]. (3) Nonlinear theory [4].



The possibility of applying the linear theory to the calculation of the characteristics of wings moving near the ground or a free surface is even more limited. Near the interface of the mediums, the dependences $c_y = f(\alpha)$ and $m_z = f(\alpha)$ are essentially nonlinear, even for wings with large aspect ratios. At small relative distances from the wing to the interface ($\bar{h} = h/b$), the linear theory only gives a reliable result at small angles of attack (Fig. 4). Large subcritical (landing) angles α are also of practical interest.

The calculation of the characteristics of wings with a deflecting leading edge or with flaps (notched vanes) by the linear theory is also limited to small angles of attack and small angles of deflection of the flaps (Fig. 5).

Fig. 5. KEY: (1) Experiment (plate). (2) Nonlinear theory [5]. (3) Linear theory [1].



Thus, the linear theory of the lifting surface only gives us unconditionally reliable results when calculating both overall and distributed characteristics at very small angles of attack ($\alpha \sim 0$). One should be extremely careful in extending these results to angles of attack which differ significantly from zero.

In conclusion, we will point out that the nonlinear theory of the lifting surface [3] based on more general prerequisites has many more possibilities for practical application.

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